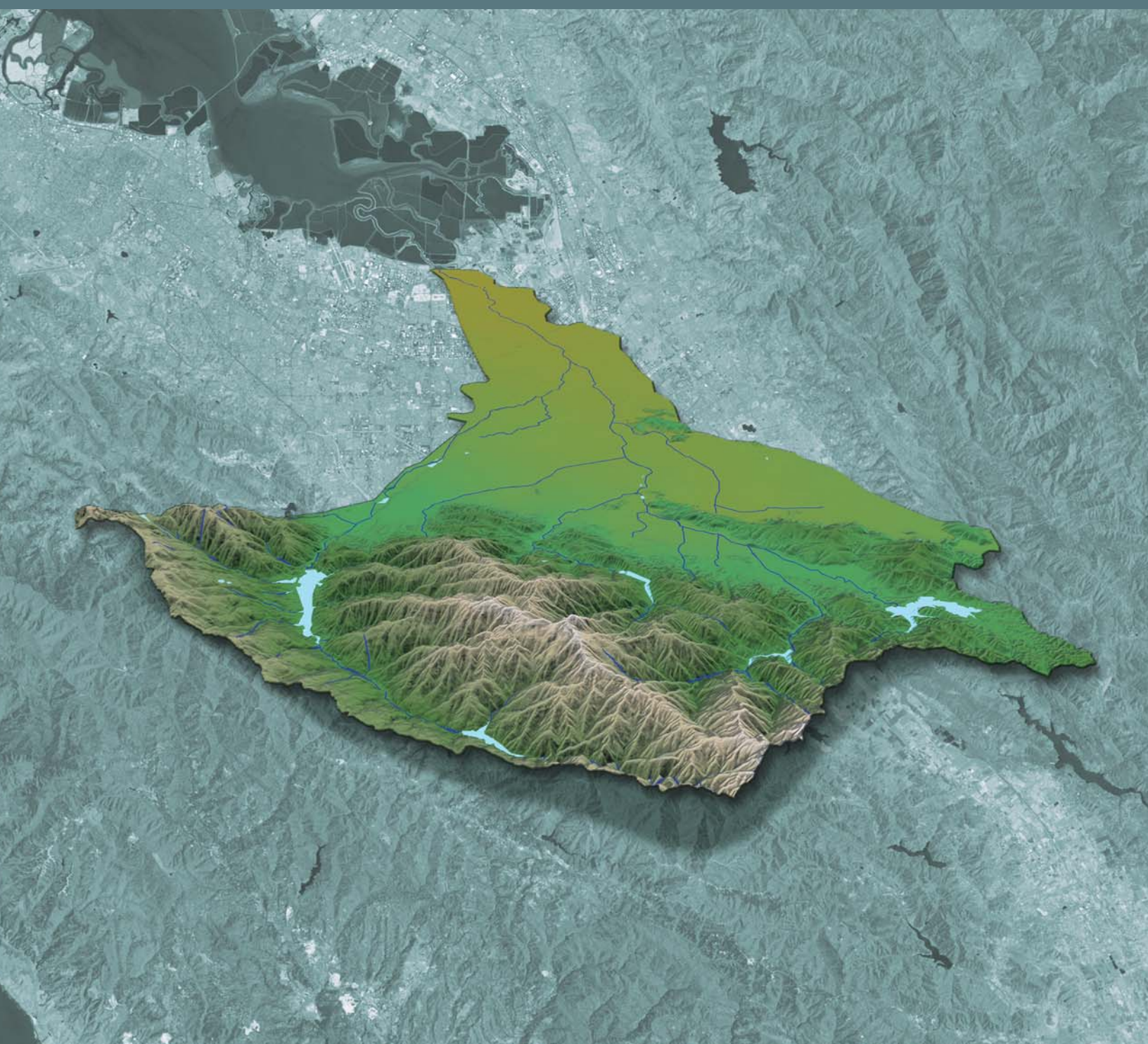


GUADALUPE RIVER WATERSHED MERCURY TMDL PROJECT FINAL CONCEPTUAL MODEL REPORT

MAY 20, 2005



Prepared for:

San Francisco Bay Regional
Water Quality Control Board
1515 Clay Street, #1400
Oakland, CA 94612

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RESEARCH & DEVELOPMENT

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TABLE OF CONTENTS

Acknowledgements.....	ix
Executive Summary	x
1.0 Introduction	1-1
1.1 Role of the Conceptual Model in the Development of the Guadalupe River Watershed Mercury TMDL	1-2
1.2 Guide to the Conceptual Model – Report Organization	1-3
2.0 Watershed Characterization	2-1
2.1 Watershed Description and System Characteristics	2-1
2.2 Comparison to Other Mercury and Gold Mines in California	2-21
3.0 Data Summary	3-1
3.1 Wet Season Creeks and River Sampling	3-1
3.2 Wet Season Sediment Sampling	3-26
3.3 Dry Season Reservoirs	3-31
3.4 Fish Tissue Mercury Data	3-36
4.0 Estimated Mercury Loads	4-1
4.1 Description of How Each Source is Assessed	4-1
4.2 Approach to Estimating Loads and Uncertainties	4-6
4.3 Transported Loads Throughout the Watershed (Wet Season)	4-7
4.4 Reservoir Production and Export of Methylmercury (Dry Season)	4-9
4.5 Upper Watershed Creeks	4-11
4.6 Creeks Below Impoundments	4-12
4.7 Urban Creeks	4-14
4.8 Impoundments	4-16
4.9 Uncertainty in Upper Watershed Loads	4-18
4.10 Guadalupe River	4-19
4.11 Uncertainty in Guadalupe River Loads to San Francisco Bay	4-20

4.12	Recommended Averaging Time for Guadalupe River Loads to San Francisco Bay	4-23
4.13	Conclusions.....	4-24
5.0	Conceptual Model of Mercury Behavior in the Guadalupe River Watershed.....	5-1
5.1	Overview of Mercury Transport Processes	5-1
5.2	Overview of Mercury Transformation and Biological Uptake.....	5-3
5.3	Mercury Behavior in Reservoirs: Knowns and Unknowns	5-8
5.4	Mercury Behavior in Creeks: Knowns and Unknowns.....	5-13
5.5	Mercury Behavior in Guadalupe River: Knowns and Unknowns	5-16
5.6	Mercury Bioaccumulation in Fish	5-21
6.0	Summary.....	6-1
6.1	Mercury Sources and Loading	6-1
6.2	Mercury Production, Fate & Transport Processes.....	6-3
6.3	Mercury Bioconcentration and Bioaccumulation in Fish.....	6-3
7.0	References.....	7-1

LIST OF TABLES

Table 2-1	Past Sediment Removal Operations in Guadalupe River Watershed	2-8
Table 2-2	Reservoir Capacity and Drainage Area of Reservoirs of Guadalupe River System (ALERT, 2003).....	2-9
Table 2-3	Size of Subwatersheds in Guadalupe River Watershed	2-9
Table 2-4	Acreage of Existing (1995) Land Uses for the Guadalupe River Watershed	2-10
Table 2-5	Production of Mercury from Major Mines in New Almaden Mining District (Bailey and Everhart, 1964 and Cox, 2000)	2-13
Table 2-6	Mercury Concentrations in Stream Water Samples Draining Almaden Quicksilver County Park.....	2-20
Table 2-7a.	Summary of Mercury Mines in California Used in Analysis.....	2-21
Table 2-7b.	Summary of Gold Mines in California Used in Analysis	2-22
Table 2-8.	Summary of Mercury and Methylmercury Data for Water Samples from the Guadalupe River Watershed	2-23
Table 2-9.	Summary of Mercury and Methylmercury Data in Water Samples from Waterbodies near Gold and Mercury Mines in California.....	2-24
Table 2-10.	Summary of Mercury and Methylmercury Data for Sediment from Guadalupe River Watershed.....	2-26
Table 2-11.	Summary of Mercury Data in Sediment from Waterbodies near California Gold and Mercury Mines.....	2-27
Table 3-1.	Flows for Reservoir Tributaries and Outlets, Wet Season Sampling 2004.....	3-4
Table 3-2.	Flow Measurements for Element 2 Sampling Locations, Wet Season 2004.....	3-10
Table 3-3.	Comparison of Dry and Wet Season Results for Alamitos and Guadalupe Creeks	3-15

Table 3-4.	Flow Measurements at Elements 3 and 4 Sampling Locations, Wet Season 2004.....	3-20
Table 3-5	Summary of Fish Mercury Measurements from Guadalupe River Watershed	3-36
Table 3-6	Summary of Adult Largemouth Bass Mercury Data	3-37
Table 3-7.	Summary Of Age-1 Largemouth Bass Mercury Data.....	3-39
Table 3-8.	Summary of California Roach Mercury Data.....	3-41
Table 3-9.	Paired Mercury Measurements In Adult Largemouth Bass And Impoundment Water Samples.	3-44
Table 3-10.	Paired Mercury Measurements In Age-1 Largemouth Bass And Impoundment Water Samples.	3-46
Table 3-11.	Summary of Stream Sampling Mercury Data.....	3-48
Table 4-1.	Creeks Affected by Mining in Upper Watershed	4-11
Table 4-2.	Estimated Wet-Season Total Mercury Loads from Upper Watershed Creeks	4-11
Table 4-3.	Estimated Wet-Season Methylmercury Loads from Upper Watershed Creeks	4-12
Table 4-4	Estimated Mercury Loads in Alamitos and Guadalupe Creek (in grams over the wet season, (10/1/2003 to 5/31/2004)).....	4-15
Table 4-5.	Mercury Loads in Urban Creeks in the Guadalupe River Watershed (in grams over the wet season, (10/1/2003 to 5/31/2004)).....	4-16
Table 4-6.	Estimated wet and dry season exports of total and methylmercury from the reservoirs.	4-17
Table 4-7.	Estimated Mercury Loads in the Guadalupe River (in grams over the wet season, (10/1/2003 to 5/31/2004)	4-19
Table 5-1.	Statistical Summary of Total Mercury, mg/kg in Reservoir Sediment Samples from March 2005.....	5-11
Table 5-2.	Comparison of Wet Season Sampling Results for Urban Creeks	5-15

LIST OF FIGURES

Figure ES-1. Location of Guadalupe River Watershed.	xi
Figure 2-1. General topography of Guadalupe River Watershed.	2-2
Figure 2-2. Major waterbodies and subwatersheds of Guadalupe River system.	2-3
Figure 2-3. Measured rainfall for selected rain gauges in the Guadalupe River Watershed.	2-4
Figure 2-4. Measured flow for selected gauges in the Guadalupe River Watershed.	2-6
Figure 2-5. Year-to-year variability in total wet weather outflows from the Guadalupe River Watershed.....	2-7
Figure 2-6. Map of major mine-related features	2-12
Figure 2-7. Map of former mining area with summary of total mercury data following remediation in AQC Park in 1994-1996.	2-15
Figure 2-8. Location of exposed mine wastes and seeps along the tributaries to the Guadalupe River.	2-16
Figure 2-9. Examples of calcine deposits and other mine wastes in or near creeks.	2-18
Figure 2-10. Wet-weather sampling locations used in 2003 for Almaden Quicksilver County Park by SCPRD.....	2-19
Figure 3-1. Sampling Locations for Upper Watershed Creeks and Reservoir Outlets	3-2
Figure 3-2. Rainfall measured at selected gages during the sampling period for this study.....	3-3
Figure 3-3. Total and dissolved mercury in reservoir watershed water samples.....	3-5
Figure 3-4. Box Plots for reservoir tributaries a) total mercury and b) methylmercury	3-8

Figure 3-5.	Sampling Locations of Creeks, Affected by Mining Below Impoundments	3-9
Figure 3-6.	Total and dissolved mercury concentrations in Alamitos and Guadalupe Creeks and tributaries.	3-12
Figure 3-7.	Mercury species along Guadalupe and Alamitos Creeks in April 2004.	3-14
Figure 3-8.	Location of potential erosion sites along the tributaries to the Guadalupe River.	3-16
Figure 3-9.	Examples of sediment erosion and bank undercutting sites.	3-17
Figure 3-10.	Sampling Locations for Urban Creeks and the Guadalupe River.....	3-19
Figure 3-11.	Box Plots Comparing Suspended Sediment, Total and Methylmercury for Urban Creeks and Upstream Tributaries to Guadalupe River.	3-21
Figure 3-12.	a)Total and Dissolved Mercury for Moderate Flow Event February 26-27, 2004 and b)Total and Dissolved Mercury for Small Storms – April 2004.	3-23
Figure 3-13.	Particulate Mercury Concentrations by Waterbody Group.....	3-24
Figure 3-14.	Particulate Mercury (mg/kg) at key locations in Guadalupe River Watershed from 2004	3-25
Figure 3-15.	Box Plots Comparing Suspended Sediment, Total and Methylmercury for Guadalupe River Main Stem to Inputs.....	3-27
Figure 3-16.	Sediment Sampling Locations for Wet Season 2004	3-28
Figure 3-17.	Total mercury concentrations (mg/kg) in Sediment Samples at Key Locations in the Guadalupe Watershed in 2004	3-30
Figure 3-18.	Depth Profiles of Temperature and Dissolved Oxygen for Almaden and Guadalupe Reservoirs	3-33
Figure 3-19.	Comparison of a) Total Mercury and (b) Total (unfiltered) Methylmercury in Almaden and Guadalupe Reservoirs.....	3-34
Figure 3-20.	(a) Total mercury, (b) methylmercury, and (c) TSS in Almaden and Guadalupe Reservoir Outlets as measured during the Synoptic Survey in 2003 and during the wet and dry season sampling in 2004. .	3-35
Figure 3-21.	Mercury concentrations for standardized 40 cm largemouth bass.....	3-38
Figure 3-22.	Mercury concentrations for standardized 8 cm largemouth bass.....	3-39
Figure 3-23.	Stream sampling sites in the Guadalupe Watershed (SCVWD, 2004).	3-40
Figure 3-24.	Mercury concentration in California roach collected at six sites in the Guadalupe River Watershed.....	3-42
Figure 3-25.	Summary of 2004 fish sampling results.	3-43

Figure 3-26. Relationship between mercury concentrations in adult largemouth bass and methylmercury concentrations in surface (A) and hypolimnetic (B) waters samples.	3-45
Figure 3-27. Relationship between mercury concentrations in average age-1 largemouth bass and methylmercury concentrations in surface (A) and hypolimnetic (B) waters samples.....	3-47
Figure 3-28. Relationship between mercury concentrations in California roach and unfiltered methylmercury concentrations in water samples.....	3-48
Figure 4-1. Estimates of total mercury loads in the Guadalupe River Watershed.	4-7
Figure 4-2. Estimates of methylmercury loads in the Guadalupe River Watershed. .	4-8
Figure 4-3. Estimates of dissolved mercury loads in the Guadalupe River Watershed.	4-9
Figure 4-4. Estimates of internal methylmercury production in Almaden and Guadalupe Reservoir during the 2004 dry season.....	4-10
Figure 4-5. Estimates of downstream exports of methylmercury from Almaden and Guadalupe Reservoir during the 2004 dry season.....	4-10
Figure 4-6. Aerial photograph of Lake Almaden and vicinity showing deposition areas at mouths of Guadalupe and Alamitos Creeks.....	4-13
Figure 4-7. Uncertainty in the single-year estimate (2003-2004 wet season) of total mercury loads from Guadalupe River to South San Francisco Bay.....	4-22
Figure 4-8. Uncertainty in the multi-year estimate (1960-2001 wet seasons) of total mercury loads from Guadalupe River to South San Francisco Bay.....	4-22
Figure 4-9. Uncertainty in the multi-year estimate (1960-2001 wet seasons) of total mercury loads from Guadalupe River to South San Francisco Bay using two different correlations between flow and suspended solids.....	4-23
Figure 4-10. Average annual mercury loads as a function of averaging period.	4-24
Figure 5-1. Transport to reservoirs.....	5-2
Figure 5-2. Creek/river processes at high flow.	5-3
Figure 5-3. Creek/river processes at low flow.	5-4
Figure 5-4. A possible pathway for accelerated weathering of mercury solids.....	5-5
Figure 5-5. Mercury methylation reducing bacteria.	5-7
Figure 5-6. Uptake of sulfate-methylmercury	5-7
Figure 5-7. Food chain biomagnification of methylmercury	5-8
Figure 5-8. Average concentrations of total mercury and methylmercury in the central part of the four reservoir systems in the dry season.....	5-9

Figure 5-9. Hypothesized relationship between sediment mercury and methylmercury concentrations in water.....	5-11
Figure 5-10. Dissolved methylmercury in creeks downstream of the reservoirs, July 2003	5-14
Figure 5-11. Percent of Flow Contributed by Urban Creeks to Guadalupe River at Highway 101 Gauge	5-19
Figure 5-12. Bioaccumulation model for the trout food web in New Zealand Lakes..	5-23
Figure 5-13. Annual hydrologic cycle in reservoirs: temperature, dissolved oxygen, and methylmercury.	5-27

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EXECUTIVE SUMMARY

The Watershed: The Guadalupe River Watershed is a large (170 sq. mi.) complex hydrologic system, comprised of six major reservoirs and over 80 miles of streams and rivers. The watershed includes dense forests in its headwaters, at elevations greater than 3,000 feet, and in its mid and lower sections large expanses of housing, and extensive commercial development, the latter supporting services, manufacturing, and the Silicon Valley technology enterprise. At sea level, the Guadalupe River discharges into San Francisco Bay (Figure ES-1).

Mercury Concern: The watershed also contains the New Almaden mercury-mining district, the largest mercury producer in North America. From 1846 to 1975 over 84 million pounds of mercury were produced and shipped, mostly to support the California gold rush. Elemental mercury, a liquid metal at room temperature, was used during the extraction of gold from ore. A comparison of mercury data from water and sediment samples from other gold and mercury mines showed that creeks near mercury mines have higher mercury concentrations than gold mines.

Not all of the mercury left the mining district, however. Most of the mercury remaining in the watershed exists as relatively insoluble mercury sulfides in mine wastes that have accumulated in reservoir deposits and sediments, and in stream bottoms, banks and flood plains. Because of the strong association of mercury with solids, the movement of mercury in the watershed is closely tied to the transport of sediments. The high variability of mercury transport is related to the highly variable flow, sediment load, and transported mercury concentrations measured during the wet season.

Total mercury concentrations in the streams that drain the mining areas were up to 6,667 ng/L in the Mine Hill tributary to Jacques Gulch, which enters Almaden Reservoir (SCPD, 2003). The range of total mercury concentrations measured in the outlets of four reservoirs during the dry season of 2003 was 2.7 – 12.8 ng/L and 7.2 to 49.2 ng/L in the dry season of 2004, compared to 1.4 to 20.0 ng/L in 2003 and 3.5 to 42.8 ng/L in 2004. Methylmercury concentrations in the reservoirs within the mining area are exceptionally high. Maximum methylmercury concentrations in the samples

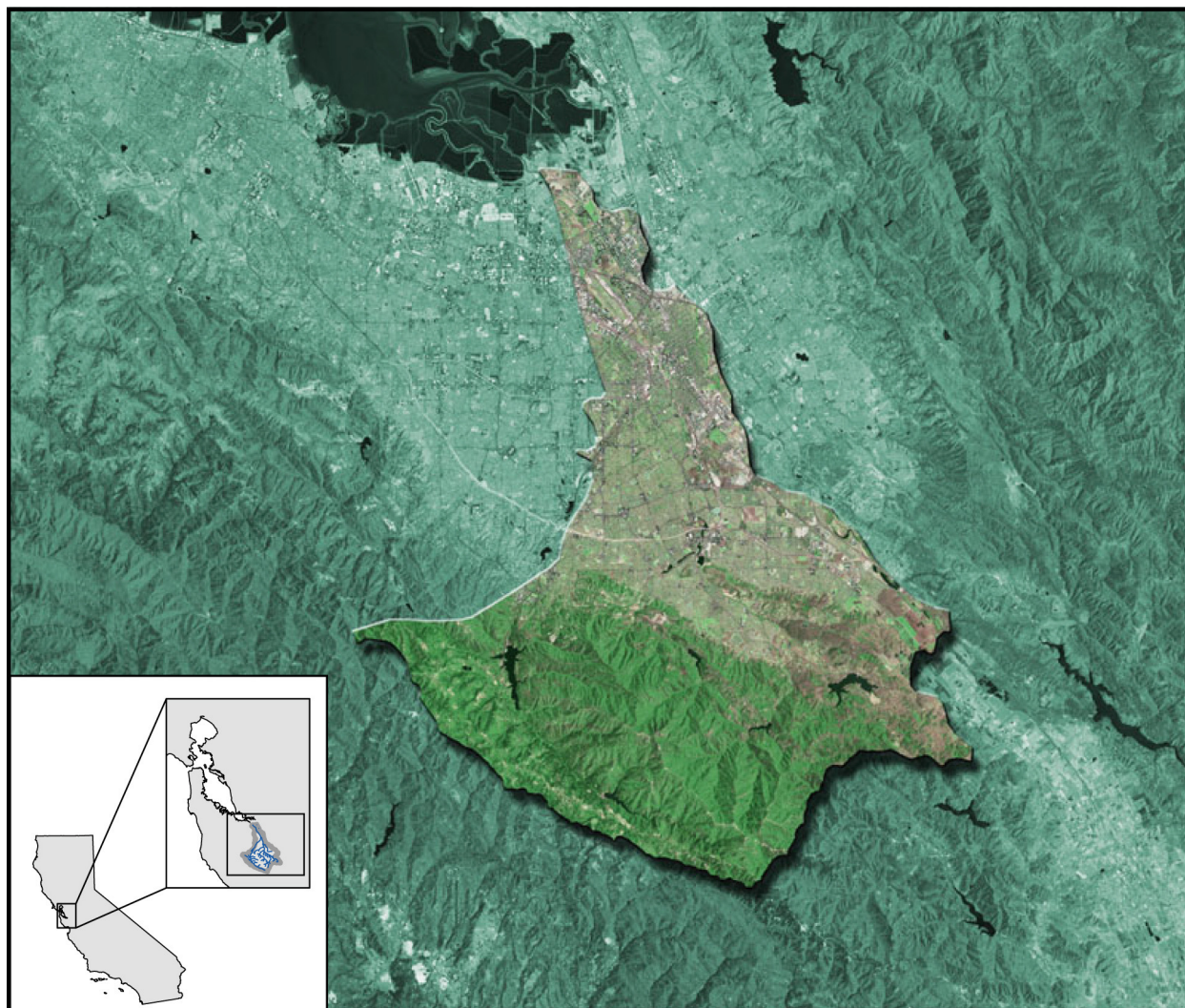


Figure ES-1. Location of Guadalupe River Watershed.

from the reservoir outlets, representing the deeper portion of the hypolimnion, were 7.2 ng/L in Almaden Reservoir and 12.8 ng/L in Guadalupe Reservoir. The problem with mercury, in particular methylmercury, is that it bioconcentrates in the aquatic food chain, producing high mercury concentrations in fish. Fish mercury levels in some of the waterbodies exceed consumption criteria. This has led to fish advisories and postings.

In 1998, in accordance with Section 303 (d) of the Clean Water Act, the California State Water Resources Control Board and the Regional Water Quality Control Board, San Francisco Bay Region listed several waterbodies in the Guadalupe River Watershed as being impaired due to mercury:

- Guadalupe River
- Guadalupe Creek
- Alamos Creek

- Guadalupe Reservoir
- Calero Reservoir

This impairment listing necessitates the calculation of a Total Maximum Daily Load (TMDL) of mercury for the watershed. The TMDL in essence identifies the maximum amount of mercury that can enter the waterbodies without resulting in the contravention of water quality based standards.

For complex pollutants such as mercury, and in a complex watershed, such as the Guadalupe, the calculation of a TMDL is similarly complex. Formulation of a conceptual model for the system that describes the current understanding of mercury behavior in the watershed can be extremely helpful. In particular the conceptual model describes the processes likely to be controlling mercury transport and fate and identifies additional data needed to address important uncertainties.

The conceptual model is actually a set of statements that describe the current understanding of mercury behavior in the watershed. The uncertainties identified during the conceptual model formulation become the basis for additional field and laboratory investigation. For most other pollutants this is a relatively straightforward process. For mercury, arguably the most complex of all water quality constituents, this requires ongoing efforts of analysis and refinement.

The Conceptual Model: From analyses of the historical data and new results, a conceptual model is emerging for mercury behavior in the Guadalupe River Watershed. The watershed has two distinct hydrologic seasons, a wet winter season and a long dry summer season.

Wet Season: The winter season is punctuated by the advective storms that create large flows in the streams and in the main stem of the Guadalupe River. These large flows are superimposed upon lower flows not that different quantitatively from those of the dry weather season, except that water temperatures are lower. The large storms lead to flows on the main stem that may increase from 10 to over 1000 cubic feet per second (cfs) in less than 24 hours. The high flows recede over 1-2 days. In the upper part of the watershed, the reservoirs typically limit the variability of flow.

The larger rain events, particularly those preceded shortly in time by similar events, create conditions where large quantities of mercury-bearing solids are routed downstream. These solids are believed to originate from hillside drainage, stream sediments, banks, and in some cases flood plains. The larger-sized, mobilized solids in the streams are collected by impoundments created by drop structures and in-stream zones of aggregation. However, during large storms, flows can overtop these drop structures. Above the reservoirs, only suspended sediment is transported downstream, since spilling is extremely rare. Vasona Reservoir, downstream on Los Gatos Creek, spills more often, causing higher suspended solids and mercury to be transported further downstream.

The wet season is largely a season of transport. Methylmercury concentrations are much lower than observed in the outlets of the reservoirs during the warm dry season. But reagents for methylation are being moved into locations where under warmer conditions methylation can occur.

Dry Season: Biogeochemical reactions predominate during the warm dry season. The periodic high flows of winter are past and surface water temperatures increase to values of 65 to 85 °F. Over the summer, the reservoirs become stratified. Settling of particulate organic matter in summer depletes the lower waters of dissolved oxygen. The reservoirs now are net methylators of mercury. The methylmercury concentrations in the discharges of Almaden and Guadalupe Reservoirs are high, up to 12.8 ng/l. Methylmercury concentrations in the epilimnetic and upper hypolimnetic waters are less than in the discharge.

Unlike the reservoirs, the creeks in the summer were net demethylators of mercury, with most of the methylmercury in the reservoir releases being lost from the stream water within the first few miles. Although the stream sediment methylmercury concentrations indicate that methylation is occurring at some locations in the creeks, the amount of methylmercury produced is not enough to offset the loss of methylmercury.

Mercury load estimates were made based upon flow and mercury data and modeled flows for selected subwatersheds. Findings from this effort are described below:

1. Most of the total mercury is transported in the wet season, particularly during high flow events.
2. Two major reservoirs, Guadalupe and Calero are sinks for total mercury; they release less total mercury than they receive.
3. Inputs of mercury derived from mine wastes are substantially greater than atmospheric deposition inputs for Guadalupe and Almaden Reservoirs, and for Alamitos and Guadalupe Creeks.
4. The urban creeks contribute less total and methylmercury than the mine-influenced creeks.
5. The total mercury loads from the Guadalupe River have high variability due to varying rainfall from year to year, as seen in the results of a Monte Carlo analysis of loads at the Highway 101 gauging station.
6. While there are multiple uncertainties in the sources of the total and methylmercury load from the Guadalupe River to San Francisco Bay, resuspension of sediments along the main stem of the Guadalupe River and urban storm drains appear to be important contributors.

Mercury Bioaccumulation: The results of the 2004 sampling program established a baseline for fish mercury concentrations in the watershed and have demonstrated the ability to establish a predictive relationship between methylmercury concentrations in water and mercury concentrations in fish tissue. Age-1 largemouth bass (*Micropterus salmoides*) and California roach (*Lavinia symmetricus*) have been shown to be sensitive biosentinels that can be used to monitor recovery in the impoundments and creeks of the watershed. These data from the 2004 sampling program are believed to provide a strong foundation on which to build fish-tissue and aqueous methylmercury numeric targets.

The conceptual model identifies the methylmercury produced in the hypolimnion of impoundments during stratification as an important internal source of methylmercury in the watershed and also a significant entry point of mercury into the food web.

Data Gaps and Uncertainties: The *Final Conceptual Model Report* completes a series of documents developed in Phase 1 of the TMDL for Mercury in the Guadalupe River Watershed. Each document has summarized new information and contributed to the understanding of the biogeochemical processes controlling mercury transport and fate in the watershed. Several data gaps remain and additional data are needed to reduce uncertainties:

- There are large uncertainties in the source of the mercury loads estimated for the Guadalupe River at the Highway 101 gauging station. Additional mercury sampling at high flows of the main tributaries and the main stem of the river are needed to refine the present estimate.
- The predictive relationship between methylmercury concentrations in water and mercury concentrations in fish tissue are based primarily on a single set of samples. The fish data exhibit low variability and are the stronger element of the predictive relationships. An emphasis should be placed on the collection of additional water samples to more fully describe the variability of methylmercury concentrations in the water column.